CHEMISTRY

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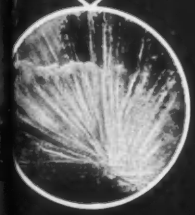

CHEMISTRY DEPARTMENT LIBRARY

Nobel Prizes of 1956 1

Practical Catalysis 6

Mechanism For Fusion Power? 17

For The Home Lab: The Story of Aluminum 19

Special Metals and Rare Earths 22

New Elements to Come 28

Nuclear Power Reactors 29

Atomic Energy and Medicine 34

Back Cover Picture: Nuclear Reactor 42

New Chemical Patents 43

Book Condensations 46

Editorial:
What Now, Dr. Smyth?
Inside Front Cover

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A SCIENCE SERVICE PUBLICATION

What Now, Dr. Smyth?

➤ WHAT THE SCIENTIFIC WORLD needs is another Smyth report. It may be difficult in these days of continuing, rigid secrecy in most matters, atomic, missile and aerodynamic, to remember back to the days just after V-J day and the explosion of atomic bombs over Hiroshima and Nagasaki.

Dr. H. D. Smyth, Princeton professor and later to be an A. E. C. Commissioner, had written a best-seller-to-be and the extraordinary story of what fission wrought was issued with commendable completeness and promptness.

There had been a blackout on nuclear research and applications from the middle of 1940 until the latter part of 1945. Even during World War II, the discovery of the fission of uranium in Germany (1939) was published and made known to the whole world, whether because of the persistence of the habit or custom of freedom of scientific publication or whether because of the lack of realization by the Nazi as to what it could mean.

Since the Smyth report there has been an effective embargo on new atomic discoveries. What we know about the thermonuclear reaction that dangled the H-bomb over our heads has been leaked out in surmises and speculations, mostly by persons on the fringe of the atomic program or working outside the restrictions of the Atomic Energy Commission. About the application of fusion to peaceful power, the Russians have told more than we have.

Dr. Smyth should write another report. It is long overdue.

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▶ THE THREE *American inventors of the transistor are shown in the photograph above, contemporaneous with their achievement, discussing the crystal structure of semi-conductors. Left to right are Dr. Shockley, Dr. Brattain and Dr. Bardeen.*

Nobel Prizes of 1956

▶ EIGHT SCIENTISTS were added to the roll of Nobel laureates with the award of the 1956 crop of Nobel prizes in science. Five of them are Americans, and the rest are British, German and Russian.

The chemistry prize for investigation of chemical reactions, particularly that of oxygen and hydrogen was for work done in the 1930's, and the medical prize on heart and lung investigations was also for research that dated from about that time. The physics prize research, upon the transitor, is more recent, dating from 1948.

Each of the prizes this year is $38,633, which is divided among those who share each prize.

CHEMISTRY gives accounts of the researches that thus are recognized by awards of what has become the world's highest scientific honor.

XUM

Energy Release Won Nobel Award

➤ THE SEEMINGLY simple reaction of hydrogen and oxygen to form water was studied in great detail by the two scientists who were jointly awarded this year's Nobel Prize in Chemistry.

Sir Cyril N. Hinshelwood, Lee's professor of chemistry at the University of Oxford, England, and Prof. Nikolai N. Semenov, founder and permanent director of the Institute of Chemical Physics, Moscow, have investigated the various ways in which oxygen and hydrogen can combine. They have also studied the energy released by the different reactions.

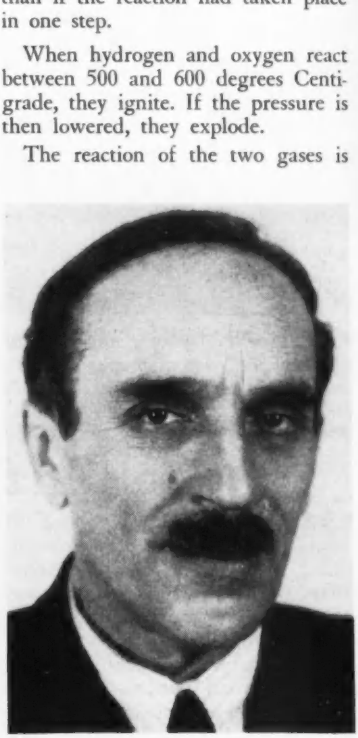
Hydrogen and oxygen can combine in proportions other than the familiar H_2O. These other compounds exist for a short time and lead to other reactions.

The interaction of hydrogen and oxygen can proceed in many ways. At ordinary temperatures, they combine when illuminated with sunlight. This is a chain reaction fundamental to photosynthesis. A number of energy changes take place one after another, the results being much greater than if the reaction had taken place in one step.

When hydrogen and oxygen react between 500 and 600 degrees Centigrade, they ignite. If the pressure is then lowered, they explode.

The reaction of the two gases is

➤ *Sir Cyril N. Hinshelwood*



➤ *Prof. Nikolai N. Semenov*

very sensitive to catalysts, chemicals that speed reactions although remaining unchanged themselves.

In an explanation of the work which two decades later was to receive the Nobel prize, Prof. Semenov wrote in the preface of CHEMICAL KINETICS AND CHAIN REACTIONS (*Clarendon Press, Oxford,* 1935):

"The theory of chain reactions does not differ essentially from classical kinetics except for the additional assumption that the chemical energy, set free in an elementary act, is not directly transformed into heat, but is spent, at least partially, in the formation of intermediate products carrying considerable energy."

Transistor Invention Recognized

➤ ONE OF industry's tiniest devices earned its three American inventors one of science's biggest awards.

The Nobel Prize in Physics for 1956 was awarded to Drs. John Bardeen of Champaign, Ill., Walter Brattain of Murray Hill, N. J., and William Shockley of Mountain View, Calif., for having invented the transistor.

A very small electronic gadget, the transistor has revolutionized the radio and telephone industry and already become a household word in this country. In the short time since its development in 1948, the transistor has found its way into use in everything from portable radios to earth satellites.

The prize-winning achievement was made by the three scientists eight years ago when they were working at the Bell Telephone Laboratories. (See photograph on p. 1).

Drs. Bardeen, Shockley and Brattain were studying semi-conductors, materials that take on the properties of both metals and insulators, depending upon the way in which they are treated.

In the study, Drs. Bardeen and Brattain found that two contacts on the semi-conductor surfaces and a connection to a germanium crystal resulted in the arrangement being an amplifier that acts very much like the larger triode vacuum tube. Since that time, transistors have replaced the vacuum tube in hundreds of electronic uses.

Made of germanium and silicon and, experimentally, of other rare metals, the transistor's small size and low power requirements make it an electronic engineer's dream gadget.

New uses for it are being found almost every other day.

Scientists trying to explain about what makes semi-conductors work talk not only about the electrons that conduct electricity, but "holes" where electrons have been and then left. Since electrons are difficult to visualize, picturing the holes that are where they were seems almost to defy the imagination.

Nobel Research Probed Heart

➤ A TINY hollow nylon tube is run up the vein in the arm to the inside of the heart. X-ray fluoroscopy is used to follow and guide the catheter as it slides along. Blood is extracted through the tube and blood pressure

XUM

is measured. The object is the study and diagnosis of heart, circulation and pulmonary conditions in health and disease.

This daring medical procedure is recognized by the 1956 Nobel Prize in Medicine awarded to two American and one German physicians engaged in medical research.

It began about 1929 when Dr. Werner Forssman at Eberswalde Surgical Clinic, Berlin, despite lack of encouragement from his colleagues, slipped an oiled tube up his arm vein into his heart.

The story is that he then walked up two flights of stairs to the X-ray room to obtain photographs proving he had actually done this. Now his pioneering is recognized by the Nobel award.

This process was utilized by the other new Nobelists Drs. Dickinson W. Richards and Andre Cournand of Columbia University's College of Physicians and Surgeons and Bellevue Hospital, New York, in more than 25 years of perfecting the catheterization method and its application for studying and understanding what happens in heart and lung diseases.

This process was used in the study of pulmonary circulation, in which the functions of lung and heart are closely associated.

Cardiac output or flow of blood, going from the right heart through the capillaries in the lung for oxygen supply and carbon dioxide elimination, has never been measured directly. To do this, blood samples are obtained before the lung is reached, which means reaching through the tube directly into the heart, and compared with blood that has left the lung on its journey through the arterial system.

The process of inserting the tube through the veins is painless as the veins have no sensory nerves.

Early in the war, the United States requested that a study of all patients who were admitted to Bellevue Hospital in a state of traumatic shock be made by this method, for knowledge of desirable treatment of battlefield shock cases.

Based on research sponsored by the Office of Scientific Research and Development and the National Research Council, precise knowledge of the state of circulation in shock, and how the state is best modified by treatment with blood substitutes: gelatin, plasma, whole blood, adrenal cortical extract, etc., was required. The volume of blood was measured, quantity lost, quality studied.

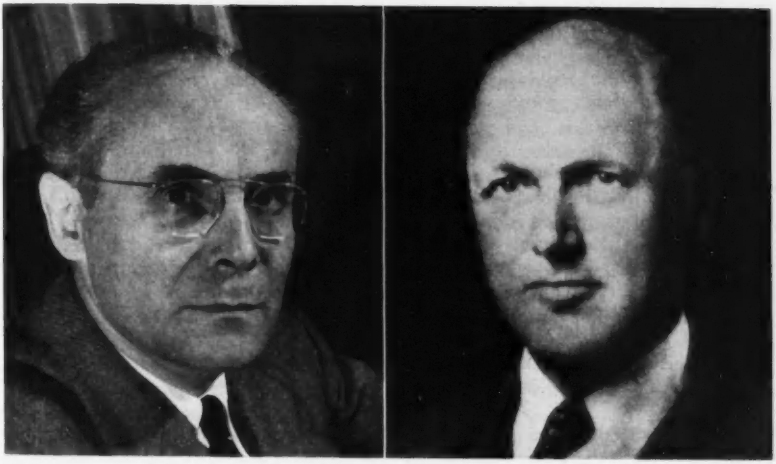
It was found by Dr. Cournand and his associates that enormous quantities of blood could be lost, and that an adequate supply would restore circulation. Blood volume and heart output can be reduced 35 to 40% in severe cases, it was found.

The catheter process serves two purposes, the proper diagnosis of certain cardiac conditions and a research method for investigating the basic performance of the circulatory system. It has saved the lives of thousands of persons by making sure they could be operated on, and it has been used to diagnose heart conditions previously not possible.

Photo Credits: p. 1, Bell Telephone Laboratories; p. 2 left, United Press, right, Fantassy of U. S. S. R.; p. 5, upper left, from book: Cardiac Catheterization in Congenital Heart Disease, upper right and lower right, United Press.

➤ HEART CATHETERIZATION — *This photograph shows how the catheter tip appears during studies of the heart's action. Here the catheter is inserted in the right saphenous vein, and the tip has been advanced through the tricuspid valve into the right ventricle.*

➤ NOBEL PRIZE WINNER — *German Dr. Werner Forssman is one of three heart specialists jointly awarded the 1956 Nobel Prize in Medicine.*



➤ AMERICAN NOBELISTS — *Dr. Andre Cournand, left, and Dr. Dickinson W. Richards share with Dr. Werner Forssman this year's Nobel Prize in Medicine.*

Catalysts Important In Human Growth, Pollution Control and Power

Practical Catalysis

An address before the International Congress on Catalysis

by EUGENE J. HOUDRY

➤ I SHALL GIVE you my own account of my years of work in catalysis, and, setting aside doubts and apprehensions, state my convictions.

In this picture I see clearly five distinct general ideas.

First was the idea, in 1924, of the regeneration of catalysts, which was born of necessity: the need to justify a business investment.

Second was the idea, in 1927, that each catalyst has its own characteristics and consequently that a proper catalyst could be found to permit me to do what I wanted—in this particular case, to make high-octane gasoline.

Third, in 1938, was a great curiosity to study the catalytic reactions in the human body, instilled by the belief that this would help to improve our research in industrial catalysis.

Fourth was the idea, in 1948, of replacing flame combustion by catalytic oxidation. In this case it was with the thought of relieving the engineer of the limitations imposed on him by the laws which govern the flammability of air-fuel mixtures.

Fifth, in 1949, was the idea that through catalysis the human machine could be protected, and, in 1955, that it could be kept in good shape longer.

As said, the first idea was born of necessity; the others were a natural evolution brought about by the catalysts themselves. During the evolution, research became my only work, experimentation my hobby, and each idea came as a reflex of nature. Concentration on a single problem at a time; choice of a simple, quick test that can be compared to a compass; a small team of devoted technicians; a room in the laboratory with a "DO NOT DISTURB" sign at the door—these are the rules.

Now then—how did the idea of regeneration come to me? In 1922 there came to our attention an experiment in which gasoline was produced by passing water gas and vapors derived from the distillation of lignite over hydrogenation catalysts composed of nickel, vanadium and cobalt. Since France lacked liquid fuels among her natural resources, we decided with a group of friends to have the experiment investigated by chemists. Two years later we were informed that the process would not be practical because the catalyst was poisoned rapidly, and replacement was too involved and costly.

The thought then occured to me to compare the nickel catalyst with the machine tools used in our shop. If we could restore our tools to use, why could we not restore the catalyst? The experts said this was not possible because others had tried and failed. When pressed for an explanation, they described how the catalyst

becomes poisoned with sulfur and carbon; and although it was possible to get rid of the poisons by passing air and hydrogen in successive steps over the catalyst, the catalyst activity would be destroyed at the same time. I left the discussion with the strong belief that to retain the activity of the catalyst all that was needed was to control the temperatures of oxidation and reduction.

Here then was the necessity, for up to that point pride and money had been spent.

A research program based on temperature control was devised. I designed the experiment and supervised the operation. It took three years of steady work on nickel catalyst to prove to my satisfaction that it could be brought back to activity by regeneration in situ; and consequently a large plant was built. The plant performed as expected, but the discovery of large quantities of crude oil rendered uneconomic this plant and all others making synthetic liquid fuels from coal.

While studying regeneration, many ideas were born—thousands of them—ideas of realization. The same kind of ideas that you all have every day when you work together—they come from everywhere, from everybody. The difficulty, as always in research, was timing: select the one which should be tried first.

From a practical standpoint we established firmly that the most important factor in regeneration of nickel catalysts is temperature control.

To reach this conclusion we had to overcome other difficulties. The experiments started with the use of pumice stone as support, with the result that the nickel would collect at the bottom of the catalytic converter. Then we blended the nickel hydroxide with china clay and extruded the mixture in pellet form and compared this catalytic composition with nickel deposited from a nickel nitrate solution onto a highly porous ceramic support. In experimenting with these differently prepared nickel catalysts, the marked difference in their behavior indicated clearly that an efficient, durable catalyst cannot be made out of a single element.

To broaden our knowledge of regeneration we experimented with many inorganic materials besides nickel. From the results obtained it was apparent that each of these catalysts reacted differently and amazingly in the process of making light hydrocarbons out of heavy hydrocarbons.

From the theoretical standpoint during this study I acquired gradually a conception of catalysis which has been the anchor of my thinking. The great names must be mentioned: Berzelius, Liebig, Ostwald and Sabatier. What I had seen made me believe in Liebig's statement that the "so-called catalytic agent, whether an inorganic substance or a ferment, was unstable and that in the course of its decomposition it induced otherwise unreactive substances to undergo chemical change." Years later Liebig gave up his claim and, I believe, made a mistake, for all I had seen induced me to adopt as a law the hypothesis of Sabatier (which repeated Liebig's first concept), and I can do no better than to quote Sabatier in his own language:

➤ EUGENE J. HOUDRY *holds the Oxycat, an oxidation catalyst which he developed to eliminate harmful fumes and objectionable odors from internal combustion engines and industrial plant stacks.*

"La théorie de la catalyse par les réactions intermédiaires comporte encore beaucoup d'obscurités, et elle a le défaut de s'appuyer assez fréquemment sur la considération de produits hypothétiques qu'on n'a pas encore su isoler. Mais elle est la seule qui puisse expliquer les catalyses en système homogène, et elle a l'avantage de pouvoir s'appliquer à tous les cas.

"En ce qui me concerne, cetta explication par des combinaisons temporaires instables a été le phare directeur de tous mes travaux sur la catalyse: sa lueur s'éteindra peut-etre dans l'avenir, parce que des clartés encore insoupçonnées se lèveront plus puissantes dans le champ mieux défriché de nos connaissances chimiques. Actuellement telle qu'elle est, malgré ses imperfections et ses lacunes, la théorie nous paraît bonne parce qu'elle est féconde et permet de prévoir utilement des réactions."

Sabatier speaks of his theory as a lighthouse whose beam might fade in the light of newer concepts. So far as I am concerned, the beam did not fail. To me:

First: the catalyst was not something just present, but, quite to the contrary, was a main reactant.

Second: catalysis was a chapter of chemistry, well defined, and limited to the chemistry of combinations unstable under operating conditions.

Third: physical preparation of the catalyst was of prime importance for its activity.

Fourth:—and above all—catalysts were marvelous tools which not only initiated and speeded up a reaction, but possessed the ability, depending on their origin, to orient the reaction toward end products widely different in quality when processing complex mixtures of molecules.

From this last thought came in 1927 the idea that a proper catalyst could be found which would transform heavy petroleum fractions into what today is called high-octane gasoline.

How was it done? I gave a long list of catalysts to our chemists to be prepared and we installed six pilot units in which to try them. The catalysts were delivered to the operators by number: one, two, three, etc.

The conditions of operation were determined as follows:

Charge stock, gas oil—capacity one gallon per hour
Space rate: one gallon per hour per five gallons of catalyst
Temperature of reaction—750°F.
Pressure—near atmospheric
Temperature maximum during regeneration—1000°F.

It was ascertained under running conditions that thermal cracking was negligible when the catalytic converter was filled with a highly porous ceramic mass.

Some catalysts were discarded in a day. When others looked of interest, gasoline yield and product distribution by weight were determined accurately.

The gasoline produced was tried for antiknock value in a racing car and, to test for stability, was exposed to sun rays.

At first the gasoline obtained was worse than the gasoline sold at the service stations. Rather than being discouraged, I felt that if catalysts could produce low antiknock gasoline there should be some which would produce a very high antiknock fuel. After months of testing, in 1928, we

came to No. 90, a blend of natural silica-alumina. I shall always remember making an Engler distillation of the condensate recovered, which, at the beginning of the run, yielded 67% by volume in the gasoline range. We stayed on late into the night until we had enough to test in the racing car—thinking, however, that with such high yield the engine would probably knock. I shall never forget my excitement the next morning when the car climbed the hill without knocking!

By 1930 the silica-alumina catalyst had been improved and thoroughly tested. It could be made easily at low cost, regenerated over and over again for months, and retain good activity.

The improved catalyst No. 90 was able to transform with excellent yields all heavy fractions of crude petroleum into stable gasoline possessing superior antiknock properties. Above all—and of tremendous import to me—was the fact that a catalyst which would make high octane gasoline had been found.

Then luck struck. A pilot plant demonstration of the process brought me to the U.S.A., to the Paulsboro refinery of Socony-Mobil—the first refinery I ever saw—and I was provided from there on with almost unlimited means both human and material. It took years of experimentation —and the decisive intervention of Sun Oil—to provide the engineers with the data and information necessary to design and build commercial plants, with the result that the catalytic cracking process was firmly established in 1937, and basically the same silica-alumina catalyst is used today throughout the world, in all catalytic cracking units.

I cannot possibly express adequate ly my gratitude to all who gave me assistance in every way. They are responsible for the fact that my first and second ideas eventually became practical realities.

From 1930 to 1942, besides catalytic cracking, many other applications of catalysis to the production of petroleum products were conceived and developed by the technical staff of the Houdry Process Corporation.

Every essential step of this work has been made public. Also, fundamental studies were started; suggestions, advice, orientation, were plentiful, and excellent execution was effected—I was at a brilliant school.

I have not the time to say here what I learned, and will limit myself to telling you a conclusion I reached, which is another foundation stone of my conception of catalysis. The thought occurred to all of us that we should endeavor to learn the structure of the silica-alumina catalysts we were using, and a project was started to this end. After many years of study by the methods we thought were the best, I recommended that further expenditures be abandoned until someone could provide an apparatus which would enable us to see not only the catalyst molecules but the way the atoms were arranged in the molecules, for I thought that catalytic reactions are made between atoms of the catalyst and the reactants.

At the beginning of 1942 it became necessary to produce butadiene for the synthetic rubber program. Butadiene was then obtained commercially by catalysis from alcohol or butenes, both materials of strategic importance.

I was then asked to devote all my time to the problem of producing butadiene starting from butane, a raw material which was abundant.

The time element was of greatest importance. From laboratory studies done by others, I chose butane reaction under vacuum with chrome-alumina and subsequent regeneration of the catalyst, for the thermodynamic study of the endothermic dehydrogenation and the exothermic regeneration indicated that they could be brought in balance. All that was necessary was to store the heat produced during the regeneration in an inert material mixed with the catalyst in order to keep the temperature of both reactions within a narrow range.

The problem was simple; our team enjoyed starting from a single hydrocarbon molecule to obtain simple molecules of hydrocarbons and hydrogen, and seven months later, working three shifts, we had a butadiene unit operating which had sufficient capacity to guarantee success on a commercial scale.

Ever since 1938, after catalytic cracking had been established, I had been anxious to participate in some way in the study of the catalytic reactions—or enzyme reactions as the biochemist would say—of the human machine—the supreme catalytic machine. This curiosity—Idea No. 3—was motivated, as already stated, by the belief that I might find some clue to a way for improving our practical results in the field of industrial catalysis.

At the end of the second world war my curiosity was rewarded to this extent: we were brought into contact with a cancer research center and then created our own research group at the Houdry Process Corporation for the purpose of trying to contribute by chemical research. We learned that the living cancer cell results from a catalytic change in the enzymes of a normal cell, and consequently researchers in catalysis might help to solve the cancer problem. In our case, when confronted with catalysts going wrong, we either regenerate or replace. In the cancer case—regeneration? of what? —replacement of enzymes? which ones? If we knew this answer, ways might be found to regenerate and/or to provide the machine with new enzymes.

As a starting point we proposed the use of carbon isotopes, and consequently produced and experimented with Carbon 13. We also synthesized a carcinogenic material tagged with Carbon 14 and conceived the possibility of finding it in the cancer tumors produced on animals.

As a result of this contact, and because biochemists teach that the human machine is essentially a machine for producing energy as is an automobile engine, I felt encouraged to pursue this line of research.

From the oxidation of food, body functions result, and consequently the oxidation enzymes are the main reactants. When the child is born the independent period of growth to maturity, which has a span of about twenty years, begins, during which the oxidation of food is so controlled as to insure the decreasingly rapid rate of growth of the machine. Thereafter the phenomenon of oxidation through enzymes is the most important thing in the chemistry of

life, and a comprehension of what might be done with the body as a machine comes within the realm of our thinking.

Catalytic oxidation persisted so in my mind that at the beginning of 1948 I could no longer resist the urge to give most of my time to the catalytic oxidation of organic substances to water and carbon dioxide, for I felt certain that this line of research would eventually lead to discoveries of importance in industry and nature.

The concept was complex: industrial application, cancer threat, and enzymes in life. There was one link: the probability that inorganic oxidation catalysts and enzymes were closely related.

I then decided to concentrate on oxidation catalysts for industrial achievement and keep informed on the developments of biochemistry. I knew that industrial catalysts could easily oxidize air-fuel mixtures to carbon dioxide and water disregarding factors in flame combustion such as temperature of ignition, inflammability limits, chemical equilibrium of carbon dioxide and carbon monoxide.

Idea No. 4, to produce heat and power by catalysis, was conceived on the above basis. It was apparent that catalysts would provide the most practical solution for heat recovery in waste gases, an old problem—and for generating energy in gas turbines. It was not necessary to be a specialist in gas turbines to think as I did in 1948. We had used gas turbines since 1936 and were certain that for successful application to automobiles the efficiency and flexibility had to be improved.

To improve efficiency it was apparent that catalysts would, first, permit complete oxidation of the fuel under all operating conditions of the turbine; second, permit reaching the maximum temperature tolerated by the turbine blade in a single step; third, reduce cost of the multi-stage turbine for the reason that fuel only would have to be added between stages in order to consume the oxygen contained in the compressed air.

To improve flexibility: fuel could be admitted in any desired quantity for all power requirements of the turbine.

However, to realize those advantages it was necessary to develop an oxidation catalyst of high activity and long life.

How was it done? The same procedure was followed as we used for catalytic cracking. A list was compiled of the catalytic compositions mentioned in literature, and many others suggested by our research team, and the catalysts were made. Very simple tests were devised: one of laboratory bench scale for determination of the initial activity and one using as a source of energy the exhaust gases from a stationary internal combustion engine running twenty-four hours a day to determine life of the catalyst, influence of poisons, and physical changes.

Early in 1950 we had developed a catalytic composition and structure which is now known as the Oxycat. The porcelain structure was conceived to minimize pressure drop and direct heat exchange between reactants and the catalysts, and at the same time bear temperatures as high as 2000°F. On such a structure a catalytic film

of two thousandths of an inch thickness was found to be adequate for maximum activity and useful life.

The best way to attach the catalytic film to the porcelain was indicated by Professor Einstein's claim that "According to the molecular kinetic theory, in a colloidal solution there is no difference between a suspended particle and a molecule." Previous to this claim, Professor Jean Perrin, in his admirable study of the Brownian movement, had come to a qualified conclusion of a similar nature.

We first tried mechanical grinding, with little success, so we acquired a colloid mill, and were able to not only produce catalytic films of high activity, but also attached them firmly to porcelain and resistance wires.

Subsequently the porcelain catalyst was installed in connection with a gas turbine running on waste gases and produced heat and energy at a constant level for 16,000 hours, a performance which justifies the thought that catalysis would relieve the engineer of the limitations imposed on him by flame combustion.

Recently catalysts on resistance wires have been commercially installed on electric ranges to eliminate odor, grease and smoke in our homes.

In 1948 and 1949, during the period of search for better oxidation catalysts, the possibility that we might do something to help the human machine through catalysis presented itself.

Atmospheric conditions unfavorable to inhabitants and seriously damaging to plant life, but useful as a signal alarm to mankind, existed in Los Angeles. The Air Pollution Control District of Los Angeles, with vision, imagination and means of investigation, publicized the fact that large quantities of hydrocarbons are emitted daily by automobiles, incinerators and industry into the atmosphere and contribute to smog.

What happens to these hydrocarbons, some of them on the carcinogenic list, when submitted to sunlight was in 1948 a question raised by Dr. Haagen-Smit that is only now being answered by Dr. Paul Kotin.

My interest in smog was intensified by the fact that I shared the feeling with others that the higher than normal increase in cancer of the lungs was due to the hydrocarbons emitted by our ever increasing number of automobiles. I could foresee that if the experiments made on animals with carcinogenic hydrocarbons would apply to humans, the future looked dark for the health of our nation unless a cure for cancer could be found.

Meantime, while a cure was being sought, it was apparent that hydrocarbons in automobile exhaust gases could be transformed into harmless products before reaching the atmosphere, and that oxidation catalysts were the most practical tools to do it.

In 1950 there was no general interest in exhaust gases from passenger cars, and the fact will remain that when the Air Polution Control District of Los Angeles County announced that automobiles were the greatest contributor to the smog situation, it was met with skepticism and denials.

I went to Los Angeles to get firsthand information from the authorities and learn the conditions of the automobile exhaust problem. Low cost,

easy installation on every car, no effect on performance of the engine, hydrocarbon elimination above 80%—these were the principal requirements for consideration.

In addition to those requirements there were other serious difficulties, for no single factor of the catalytic reaction remains constant: space rate, temperature and chemical composition vary considerably over the range of operation; that is—idling, cruising, full speed, acceleration and deceleration. The quality of the gasoline varies with the type and quantity of the additives—carburetors easily get out of order—and so forth.

At first, in fact, the problem seemed insurmountable, for the catalyst to be efficient, and for its protection, the temperature of reaction has to be kept within narrow limits. After eight years of steady work we have a solution which I believe meets all requirements. There has been no short cut—it took three years of careful study of heat exchange in relation to the thermodynamics of exhaust gases to produce a catalytic exhaust for engines using unleaded gasoline.

It took five more years to find and control a catalyst which would resist lead poisoning and remain efficient over a period of one year of normal driving, and this has been the most difficult task in my years of research.

How has the problem—or perhaps I should say 'puzzle'—been solved? By experimentation and perspiration—as the great Edison used to say. Influence of each variable on the reaction was determined, and classification of the importance of each variable resulted. Among all those variables, finding the range to keep reaction temperature practically constant, while the catalyst aged, was time consuming. Moreover, there was no analytical method in existence for determining accurately hydrocarbon elimination and thus indicating performance. Spot sampling was unsatisfactory, and we were unable to reach the goal until we ourselves had developed a continuous method of analysis using infra-red equipment.

I am obliged to emphasize the great menace that air pollution is to mankind. All investigations made in the last few years by reputable scientists have demonstrated clearly that the menace is growing and must be fought.

The results obtained so far confirm the thought that catalysis will provide us with the most practical tools to help us win this fight.

At the beginning of 1955, industrial oxidation catalysts indicated to me that, if enzymes were related to them, something more important than cleaning the air could be done for human life. What then are the known relations between oxidation enzymes and industrial oxidation catalysts?

In our generation, brilliant biochemists have made rapid progress in the field of catalysis. They have come to the conclusion that the enzyme, a catalyst, participates in the reaction and must interact with at least one of the reactants to be effective. They also liken a living cell to a factory wherein the enzymes are machines which transform starting materials into finished products, thereby inspiring our engineering mind.

It is obvious that the most important phenomenon of life is enzyme oxidation. Enzymes will transform

the carbohydrates, proteins and fatty acids into carbon dioxide, water and ash at 98°F. and atmospheric pressure.

Industrial catalysts will perform equally at higher temperatures.

Enzymes are complex molecules containing atoms of inorganic substances such as iron, copper. Last year it was announced at the Third International Congress of Biochemistry that one atom of zinc constituted a vital part of an enzyme molecule and that the zinc content amounted to 0.18% by weight.

Industrial catalysts are also complex molecules which contain in similar percentages metals which play the vital role.

Both enzymes and industrial catalysts deteriorate.

In our extensive study of the deterioration of oxidation catalysts we have found that useful life varies depending on the type of fuel and the dust contained in the air. We have also found that during its life a most important factor is the concentration of oxygen in the air-fuel mixture. There is a minimum content necessary to initiate and complete the oxidation, and a maximum content to prevent destruction of catalyst and equipment. Of great interest was the observation that to maintain complete oxidation while aging it was sufficient to increase the percentage of oxygen. The increase of oxygen to restore the activity of the catalyst need not be great, for in some of our industrial installations raising the original content from 4% to 6% was effective.

That there is a minimum and a maximum content of oxygen in the air necessary for the human machine to function, and that slight variation of oxygen content in the atmosphere makes us feel good or bad, goes without saying.

And here you have the up to date step of the evolution which has led me to the hypothesis that maintenance of the normal functioning of the human machine is possible by increasing the oxygen content in the air breathed in homes and working quarters as the body ages.

Meanwhile, the search for prevention or cure of cancer has been relentless.

Dr. Paul Kotin has proved that harmless hydrocarbons under sun rays become active and induce cancer tumors on animals.

Dr. Otto Warburg has provided the world with a discovery of extreme value—probably the greatest in cancer research—in pointing out that a cancer cell can obtain about as much energy from fermentation as from respiration, but a normal cell obtains more energy from respiration than from fermentation.

There is the fundamental change in the enzyme reaction.

There is the catalytic problem—and to solve it by regeneration and replacment should not take too long.

And so then—what has been the impact of practical catalysis in our generation? In the last two decades catalysts have invaded the oil industry, the largest producer of organic substances, while making rapid strides in many other productions of chemicals.

Catalysts have proven their capability of producing heat from waste gases at a profit, and they also have indicated their willingness, if properly

XUM

handled, to improve considerably our art of making steam and power using the energy contained in air-fuel mixtures.

Catalysts have given evidence of their strength to help win the fight against air pollution—a fight which should be given precedence by all nations over feverish preparation for war.

Catalysts have started to invade the home, to provide comfort and keep us in better health.

The field embraces the betterment of our way of life, and life itself—and consequently is boundless. We are a relatively small family of pioneers and have just started to clear the field. May these few words encourage you to pursue your research, and let us meet again to exchange ideas, for I am certain that achievements of importance will reward our efforts.

Nature's Catalytic Forces

➤ POWERFUL utilization by the chemist of catalytic forces that nature uses so abundantly in manufacturing natural products and controlling life processes was predicted for the future by Sir Hugh Taylor, Princeton University professor of chemistry, in his presidential address before the first International Congress on Catalysis.

Explaining the great progress in developing and understanding catalytic agents for speeding chemical reactions, even at very low temperatures, Sir Hugh told how changes in hydrocarbon materials by catalysis indicate that in the surface material speeding the changes there are strongly polarizing if not ionic centers.

The modification of surface catalytic agents can produce, by polymerization of monomeric materials such as isoprene, he explained, in one case the stereo-specific configuration in natural rubber and in another case that which nature produces in balata or hard rubber.

Commercial and Non-Profit Research

➤ COMMERCIAL LABORATORIES and nonprofit research institutes employed 5,000 scientists and engineers and expended $85,000,000 in 1953, a survey made for the National Science Foundation indicates.

Of the commercial laboratories' expenditures, approximately $35,000,000 was for scientific research, and about $4,000,000 for basic research, while the equivalent figures for nonprofit research institutions were more than $50,000,000 and over $3,000,000.

The Federal Government contracted with the commercial laboratories for about half of their total research expenditures, with industry responsibile for about an equal amount. The institutes had twice as much Government money as from industry.

Most of these organizations were founded since 1941 and the rapid increase is due to the Federal research programs, particularly for defense.

Solar Flares May Show Way To Harness H-Bomb

Mechanism for Fusion Power?

➤ THE SAME MECHANISM producing solar flares might be useful in controlling the H-bomb's fusion reaction for peaceful purposes.

The mechanism is the "pinch effect." It is a possible method of obtaining the high temperatures needed to fuse, or join, the light elements into heavier ones with release of energy. Generating the high heat in a controlled manner requires containers that will not melt or be otherwise affected.

Using the "pinch effect" would seem to eliminate the container problem, since the reacting gas column would contract to contain itself, thus not touch any walls.

Dr. T. Gold of the Royal Grenwich Observatory, Herstmonceux Castle, Sussex, has suggested that, in the sun, the "pinch effect" may cause the speeding up of particles, resulting in the solar flares, great arcs of hot, glowing gases thrown out of the sun's surface.

The pinch effect was described by the Russian scientist, Dr. I. V. Kurchatov when, speaking earlier this year at Harwell, Britain's atomic energy laboratory, he reported Soviet experiments on gas discharges with high density currents. Dr. Kurchatov said their observations showed the production of some particles with energies very much higher than would be expected.

The leading Russian authority on atomic energy told of studies in which temperatures near 1,000,000 degrees Centigrade were reached for very short periods of time by passing large currents through gases like deuterium, using a strong magnetic field to keep the gas ions away from the container walls.

The unexpected appearance of the few very high energy particles in deuterium was detected by the neutrons and gamma rays produced. The phenomenon, Dr. Gold observed in the British scientific journal, Nature, was always "clearly related" to the second constriction of the spark, or "pinch effect."

He says that in sparks constricted in their own magnetic field, there is a mechanism for accelerating a small fraction of the particles to high energies.

In solar flares, high energy particles are also present. Electric currents, evenly distributed through large volumes, normally flow in the vicinity of sunspots. When the current density becomes too high, an instability occurs, causing the currents to become constricted along one or several lines due to their own magnetic field.

If this interpretation of solar flares is correct, the Russian experiments would seem to provide an analytical laboratory method for further studies.

The "pinch effect" was first noted by E. Northrup in 1907. Two University of Southern California scientists have reported their studies to this

XUM

effect, and Atomic Energy Commission scientists involved in Project Sherwood, code name for the U.S. attempt to tame the fusion reaction for peaceful purposes, are believed to be working along similar lines, although their work is shrouded in secrecy.

Graphite Welded Together

➤ BOTH ATOMIC and solar energy progress got a boost at the dedication of Union Carbide's new multi-million-dollar research laboratories.

Dr. Robert G. Breckenridge, director of the laboratories, reported that graphite pieces had been "welded" together for the first time in history and that the largest single crystals of cadmium sulfide ever reported had been "grown."

Welded graphite, heretofore an impossibility, now means that scientists can prefabricate sheets and panels for the assembly of nuclear reactor moderators which now must be built from graphite blocks.

Cadmium sulfide, used in solar batteries, photo cells, and as a light-producing phosphorescent material when properly activated, has been made in single crystals measuring three-eighths of an inch in diameter and several inches long.

These single crystals have proven superior to those of a poly-crystalline film.

The key to the success of how to melt graphite together was the discovery that, when heated to a high temperature, high pressure can prevent vaporization.

This technique has already led to the production of new forms of graphite which have a much higher degree of crystalline perfection than any artificial graphite attainable up to now.

Trade Groups Do Industrial Research

➤ TRADE associations and other cooperative groups spent $21,000,000 for research and development in 1953, it is shown by a survey conducted by the National Science Foundation.

The report shows the influence research policies of cooperative organizations have upon industrial research practices. The questionnaire was answered by 543 cooperative groups—trade organizations, professional and technical societies, and research-educational cooperatives.

Dr. Alan T. Waterman, director of the National Science Foundation, said the influence on research policies of these groups is much greater than dollar expenditures alone would indicate. As an example, he cited the American Petroleum Institute, a trade association, which through its conduct of basic research has contributed much of the fundamental knowledge underlying the petroleum industry today.

The survey was conducted for the Foundation by Battelle Memorial Institute, Columbus, Ohio. It is one of a series that, when completed, will provide the first overall view of scientific research and development in the United States.

The Story of Aluminum

I. The Metal

by Burton L. Hawk

➤ I suppose that many doubts could have entered his mind.

"Why should I attempt it when so many have failed?"

"How can I afford the necessary equipment?"

"Who would be interested if I were successful?"

"What use would there be for the product?"

But, fortunately, none of these doubts overshadowed the burning desire of Charles Martin Hall to find a practical way to obtain aluminum from its ore.

We, who take aluminum for granted, find it hard to visualize that less than a generation ago the metal was virtually unknown except as an expensive laboratory curiosity to scientists. And, the irony of it all was that aluminum is the most abundant metal on earth! No one had yet found a successful method to obtain it as a free metal in any worthwhile quantity. Like the tale of the Ancient Mariner, it was a "water, water everywhere and not a drop to drink" situation. This was the situation that Charles Hall sought to correct. With home-made batteries in his home-built laboratory in the woodshed, plus a large amount of will and determination, Hall discovered the electrolytic method of extracting aluminum from bauxite which is still in use today.

But the story of aluminum goes back still further. It all began in 1759 when the German chemist Andreas Marggraf proved that alumina was a distinct compound . . . different from magnesia and lime. This certainly did not seem like an epoch-making discovery, but nevertheless it was the starting link in the long chain of events which brought us aluminum which we find so useful today.

Although Marggraf suspected that alumina contained a new element hitherto unknown, he was unable to isolate it. Sir Humphry Davy became interested in the compound also and he attempted to decompose it with his voltaic pile which he had used previously to isolate sodium, potassium, and the alkali earth metals. But the stubborn alumina would not respond. Berzelius, too, attempted to isolate the metal and was unsuccessful.

It remained for the Danish chemist Oersted to prepare aluminum for the first time in history. Suppose we let him describe the method he used in his own words:

> "Rapidly heated with potassium amalgam, it (aluminum chloride), is decomposed, potassium chloride and aluminum amalgam being formed. This amalgam is very quickly decomposed in contact with the atmosphere. By distillation without contact with the

atmosphere, it forms a lump of metal which in color and luster somewhat resembles tin."

Such was the birth of aluminum. This was a difficult and dangerous experiment. Wöhler later repeated the experiment but could not obtain the metal. He did, however, finally succeed in preparing it by a method of his own which consisted of heating anhydrous aluminum chloride with metallic potassium. This was indeed a violent reaction and the platinum crucible he used became white hot!

The French chemist Deville improved upon Wöhler's method and made large-scale production possible, but the price was prohibitive.

And so we come to Charles Martin Hall in the United States who finally solved the problem when he conceived a cheap method to obtain the evasive element. Gradually, through the years the price of aluminum has dropped from $150 to a few pennies per pound. Certainly we need not elaborate on the role aluminum plays in our economy today. It has become one of the most important and highly useful metals known.

Aluminum has three important physical properties: lightness, strength, and durability. The pure metal is silvery white but quickly becomes covered with a thin coat of oxide which gives it the familiar dull appearance. This layer of oxide is a blessing, as it prevents further oxidation and is responsible for the durability of the metal.

As it is listed high in the electrochemical series, aluminum is quite active. Place a small piece of the clean metal in a solution of dilute hydrochloric acid. Note the rapid action as the metal dissolves. Sulfuric acid also attacks the metal, but less vigorously. Strangely enough, aluminum does not dissolve in nitric acid; hence this acid may be shipped in aluminum containers and tank cars. Prepare a concentrated solution of sodium hydroxide and drop a clean piece of aluminum in it. Note the reaction. This illustrates why acids and alkalies should not be heated in aluminum saucepans.

Aluminum melts at 600 degrees. You can probably melt it in the home lab by heating it in a Bunsen burner flame. Or, you can use a blowpipe with an alcohol lamp flame. Place the metal in a porcelain crucible lid. Grasp the lid with tongs and direct the blowpipe flame onto the metal.

Aluminum burns with a brilliant white flame. Sift a *small* quantity of aluminum powder into an alcohol lamp flame. It will burn in blinding white flashes of light. Be sure to use small quantities here and guard against fire.

Aluminum is a powerful reducing agent and can be used to reduce the oxides of certain other metals. This reduction is known as the "Goldschmidt Process," named after its founder. To demonstrate the reaction, mix together equal quantities of powdered aluminum and iron oxide. *Use small quantities!* Place the mixture in a large dry fireclay crucible. Place the crucible in a bed of sand, or, preferably, outside. Drop a piece of burning magnesium ribbon into the crucible. Keep your face away! A violent reaction takes place as the aluminum combines with the oxygen in the oxide leaving the iron free. The heat is usually sufficient to melt the

iron and the reaction is used in welding ("thermit" process). After the crucible is thoroughly cool, dump the contents out and examine with a magnet for small particles of iron. If the mixture in the crucible fails to ignite with the magnesium ribbon, you can add an "ignition mixture." Mix together equal quantities of powdered magnesium and barium peroxide. Carefully pour this mixture on top of the iron oxide and aluminum mixture. When you drop the burning magnesium strip into the crucible, it will ignite the ignition mixture which will in turn ignite the basic mixture.

➤ "Who *pulled that switch?*"

Important Uses of Unusual Metals Seen

Special Metals and Rare Earths

by EUGENE B. HOTCHKISS, *Vice President, Vitro Corporation of America before the American Mining Congress 1956 Mining Show, Los Angeles, Calif.*

➤ WE QUITE customarily speak of these substances—which I shall call simply the rare metals—as though they belonged together by virtue of similar characteristics or properties. Even an inference of uniformity is hardly excusable in this age of scientific exactness, for individually the rare metals have very little in common. They are not even all "rare." They differ widely in the prevalence in which they occur in nature.

Some, common in other parts of the world, are promoted to the rare category in our country, mainly because of their strategic importance. Their value per pound ranges from cheap to very expensive; some rare metals are produced on a large scale, others by the gram.

To further compound the confusion of nomenclature, we include in this group the metalloids, with properties somewhat between those of a true metal and a non-metal, the rare earths, which are neither truly rare nor are they earths, and those new manmade elements that are produced by nuclear reaction and the transuranics.

Perhaps some justification for this blanket classification may be found in their very diversity; perhaps more in our attitude toward them that sees unmeasured potentialities in their future. A kinship of fascinating dissimilarity bonds these unusual metals together. In common, they stimulate our technical curiosity in the search for newer and better materials. Collectively, they represent the promise of the future in the metals industry.

Therefore, I propose that we borrow a term of scientific distinction used to designate other congeries of diverse talents, and call this group hereafter the College of Rare Metals, and I nominate for membership the following:

- Beryllium
- Bismuth
- Boron
- Cadmium
- Cesium
- The Alkali Earth Metals
  - Calcium
  - Barium
  - Strontium
- Cobalt
- Columbium
- Gallium
- Germanium
- Hafnium
- Indium
- Lithium
- Manganese
- Molybdenum
- Nickel

The Platinum Group
- Iridium
- Osmium
- Palladium
- Platinum
- Rhodium
- Ruthenium

Rhenium
Rubidium
Scandium
Selenium
Silicon
Tantalum
Tellurium
Thallium
Thorium
Tungsten
Vanadium
Yttrium
Zirconium

The 15 Rare Earth Metals

The Manmade Metals
- Francium
- Promethium
- Astatine
- Technetium

The Trans-Uranics
- Americium
- Berkelium
- Californium
- Curium
- Neptunium
- Plutonium
- Einsteinium
- Fermium
- Mendelevium

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Mineral Facts and Problems—Bull. 556—US Bureau of Mines
The Chemical Elements—Chem Chart Pub. 1954
Reactor Hand Book—Vol. 3, Sec. 1—USAEC 1955
Atomic Industrial Forum Publications

I will not ask that these nominations be seconded, neither will I request that the nominations be closed, and I hasten to add that this selection of some 65 of the 101 presently identified elements in the periodic table has not been passed upon, or approved by any committee. It is my own selection and admittedly arbitrary.

Let us briefly examine some of these so-called rare metals.

In prevalence, silicon, second only to oxygen as the most abundant element, makes up some 28% of the earth's crust. But pure silicon is produced at the rate of only a few thousand pounds per year. The rare metal, tungsten, is about as abundant as copper. There is almost twice as much zirconium in the earth's crust as zinc, and one is amazed to find rubidium, 16th in order of prevalence, almost as abundant as chlorine, but with a total annual production of only about 100 pounds.

On the lower end of the prevalence scale, thallium occurs in the lithosphere to the extent of about 30 grams per ton, and although it is more abundant than arsenic, antimony, or mercury, its wide distribution does not represent its availability. Rhenium, occurring in the earth's crust to the extent of only one thousandth of a gram per ton, is indeed rare, while the manmade metals like promethium, produced only by nuclear reaction, do not occur in nature at all.

In physical properties there are also some striking differences. Thallium is so soft it can be easily scratched with the fingernail. Gallium will literally melt in your mouth, going into its liquid phase at some 13° F. below normal body tempera-

ture. At the other end of this scale stands osmium, the hardest of all metals, and tungsten having the highest melting point, 6152° F.

The electrical properties of the rare metals are equally interesting. Boron, a feeble conductor at room temperature, becomes quite conductive at high temperatures. Vitreous selenium is a dielectric, while in one of its other allotropic forms it is a good conductor. Germanium owes its important use in transistors to the fact that it is a semi-conductor, and recent reports indicate lanthanum, one of the rare earths, is a super-conductor.

Variations in age are notable, too. The mineral, beryl, was mined as a gem in Egypt five thousand years ago, but the metal beryllium, the lightest stable metal with a high melting point, was not known until late in the nineteenth century. Osmium, the heaviest of all metals, was found in the native state with others of the platinum group in precious metal brought back by the Conquistadores in the mid fifteen hundreds. Mendelevium, first produced a little over a year ago, certainly qualifies as the youngest rare metal, but its half life is so short that it will undoubtedly pose some unique membership problems in the College of Rare Metals.

In the interests of brevity I shall not even attempt to catalogue the infinite variety of their chemical properties or their nuclear behavior.

These, then, are our rare metals. We have mentioned only a few and our examples were selected primarily to illustrate diverse and unusual properties. Old or new, rare in occurrence or rare in use, hard, soft, reactive, or passive, they represent a most unusual collection of substances, richly deserving the distinction and honor of membership in the College of Rare Metals.

But fascinating as they are as rare metals, the future promise of those we can coax out of their obscurity into the profitable service of mankind commands a much more practical interest. It is as *common,* rather than *rare,* metals that they will spark the new industries of tomorrow. Can we determine the factors that are significant in their transition from rarity to availability? Can a pattern be detected in the transition of recently available but once rare metals such as aluminum, magnesium, or titanium that might help us to predict when and how others might join these illustrious alumni of the College of Rare Metals?

We can list several factors that were significant in the change of these three light metals from relative obscurity to economic importance:

I. The recognized need for new, strong, lightweight structural metals;

II. The abundance of each of these three in the earth's crust that stimulated a desire to put them to use;

III. The assurance that a large and profitable market awaited the successful solution of the problems of process technology and fabrication.

How did these factors operate in the case of aluminum? About 35 years of research and process development followed the first laboratory production of the pure metal before Hall achieved his technological breakthrough that demonstrated how aluminum could be produced economically. We do not know the cost of this effort, but it is of interest that the

research, application engineering, and market development, which followed each other in orderly fashion, were solely the efforts of private risk-taking in an atmosphere of free enterprise and peace.

The story of magnesium differs from that of aluminum. The magnesium industry was a German monopoly imported to this country under the threat of World War I. Judging by U.S. production, which languished around a few hundred tons per year until there was a sharp rise in the early 30's, the problems of process technology were not solved until then. But in magnesium, the factor of need was heavily underscored by war-time strategic requirements, which, heavily backed by federal subsidy, created a tremendous demand before industry was technologically ready to supply it.

The process breakthrough had hardly occurred before the defense program of World War II expanded magnesium production manyfold, from 5300 tons from one plant in 1939 to over 180,000 tons from 15 plants four years later. At the end of the war one plant was again the sole producer. I have been unable to find records of the total federal spending on magnesium, but we may assume that it was substantial.

The titanium industry got off to an even faster start than magnesium in another period of emergency, and under the direct initiative of the government. A much more imposing array of government spending programs appeared. Again we see the factor of strategic need for a little known metal causing a crash procurement program well in advance of the process breakthrough that normally signals the start of a new extractive industry. It is estimated that the total cost of this program to the government, including government-financed research in processing and production, plant loans, the maintenance of production aids, together with G.S.A. stockpile purchases, totaled somewhere around 175 million dollars.

As far as a pattern is concerned, we can note that in each of these examples, the difficulty of extracting the metal from its ore, or source, and in fabricating it into useful forms, disputed the promise if its prevalence in nature. And in each case, a costly, arduous, and long research program had to be successfully completed before the metal became an article of commerce.

By no means should we deprecate the widespread industrially-sponsored activity that took place concurrently, nor can we deny that our economy will be enriched by the availability of this new light metal much sooner than would have been the case without vast government support. But in the case of magnesium and titanium we might raise the question whether the development of our newer metal industries must of necessity occur in an atmosphere of national urgency and be dedicated first to the destructive arts of war.

We can look at some other examples. Without doubt the history of uranium illustrates the ultimate effect of the forces of extreme national urgency, brought on by world war and continued by an unsettled peace. Never before has our national security been so thoroughly tied to a

single metal, which a short decade and a half ago was known as a little wanted by-product of radium refining. The immense problems of scarcity, lack of basic knowledge of its properties, and the gravest question of all—whether its predicted behavior could be safely demonstrated and controlled—were far beyond the capabilities of private enterprise to handle.

Under a time schedule that appeared impossible, and the necessity of the most stringent security controls, there was no other way of creating this industry except as a ward of the government. The cost, exclusive of weapons development and production, has been estimated to be in the neighborhood of 14 billions of dollars— the cost of 80 titanium programs.

We may hope that this example does not indicate a pattern to be followed in the case of other rare metals, but it brings home forcibly the vital necessity, as well as the immense cost, of the research, process engineering and solving of many complex metallurgical, chemical, and fabrication problems that were involved in the development of this new metal industry.

Molybdenum is one of the relatively few rare metals, now established as an industry, in which private initiative in research outpaces federal subsidy. The Bureau of Mines says,—

> "At least part of the spectacular growth of the molybdenum industry can be attributed to research sponsored by the producing firms."

We can cite two more examples: beryllium, where private initiative has been particularly active; and zirconium, where federal leadership is more apparent. In both cases, recent government procurement contracts for many times the present productive capacity of the industries involved, have caused a flurry of competitive bidding and crash development of new processes.

We certainly cannot object to the aspects of competition in technological development, or its effect on prices, and the plans of the zirconium producers and quite possibly those making beryllium, as well, to produce quantities in excess of government requirements, will certainly advance the industrial importance of these metals. But when a new business, or one about to be vastly expanded, has only one customer, whose requirements are dictated primarily by military considerations, we may ask ourselves again—must the peace-time uses of our new rare metals always be a by-product of their strategic war-time need?

In our present state of international nervousness, it is hard to plan effectively for the less critical times we hope for in the future. We must never forget that industrial strength is our nation's best guarantee of peace and the strongest deterrent to potential aggressors. We should of course continue stockpiling those scarce materials on which our productive capacity depends, and intensify the search in our own country for the minerals we might not be able to obtain from abroad in time of war. In fact, further progress in all of the technologies that might make us invincible in war is vital.

But neither should we forget that many of these same objectives can

also be accomplished by research and development dedicated to the objectives of making available more and better goods for a higher standard of peace-time living.

It is here that the rare metals field is particularly and adversely affected. In many cases, our knowledge of their true properties is very limited, and we have had ample demonstration of their resistiveness to extraction by classical processes. In few instances, indeed, is there assurance that a profitable market awaits. To further complicate the situation, the determination of the properties of rare metals depends in general on a much higher state of purity than is the case for the more common ones, and their preparation in anything like a pure form will often depend on the development of special techniques.

This can only be accomplished by long, arduous, and costly research; but it is particularly difficult for the small and medium-sized business enterprises interested in this field to raise the money necessary to carry on such programs. Banks will not loan the money, the business seldom generates sufficient funds, and risk capital for research is very difficult to obtain. Yet the contribution these small and medium-sized businesses can make to our national economy depends as much on this financial backing as it does on the imagination and perseverance of those leading the research.

Our experience at Vitro has taught us there is no short cut to a bonanza in this field. At what is now our Rare Metals Division, we produced the first gram of radium refined in this country, nearly 25 years ago. We have been active since 1942 in the emergency transition of uranium from rarity to relative abundance. More recently we have extended our interest to other rare metals, and the rare earths.

The reasons why we are increasingly active in this field, despite the hazards, the difficulties, and the problems I have cited—that particularly affect a medium-sized company like Vitro—are these:

We have seen in the past 20 years a phenomenal increase in the knowledge of the physical sciences, and their industrial applications. We expect this trend to accelerate in the future. The opportunity of sharing in the direction of this increasing force of technology, in attacking the immense underdeveloped wealth of rare metal resources in our land, and in the seas that wash our shores—this opportunity is to us a fascinating challenge.

In April, 1951, the first titanium ingot cast in Midland, Pa., weighed about 50 pounds; by October, 1952, the first two-ton titanium ingot had been melted.

The British have successfully treated milk by radioactivity; milk so treated will not lose its flavor and can be kept in good condition for 10 days.

Wood particle board is a practical, profitable outlet for forest thinnings and mill residuals, formerly considered waste.

XUM

Predicts Creation of Four More Chemical Elements

New Elements to Come

➤ THE SCIENTISTS who fashion synthetic atoms in the rarefied regions of the periodic table have a few tricks up their sleeves that may enable them to recreate a number of elements beyond the heaviest now known, element 101.

Elements up through 105 may be created and identified in the next few years. These elements probably existed at the birth of the earth, but, decaying through radioactivity, became extinct within minutes or seconds.

The hopes for recreating, briefly, these extinct "dinosaurs of matter" were described by Dr. Glenn T. Seaborg, the University of California Nobel Laureate who is the co-discoverer of plutonium, element 94, and all the heavier synthetic elements up through 101.

In the G. N. Lewis Memorial Lecture at Berkeley, Dr. Seaborg described in detail for the first time some of the predicted chemical and radiation properties of undiscovered elements up to and including element 105, as well as how he and his colleagues hope to make them.

Dr. Seaborg pointed out that only 17 atoms of element 101 were identified in the discovery experiments, an unimaginably small, invisible quantity of matter. As one goes up the periodic table, even fewer atoms can be made and they "die" through radioactive decay quicker. So chances of identifying recreated "dinosaur" atoms become slimmer.

Dr. Seaborg and his colleagues hope to overcome these problems chiefly in two ways:

1. With a new type atom-smasher, called the heavy ion linear accelerator, or "Hilac," built with AEC funds;

2. By keeping their counters peeled for unusual isotopes of the ultra-heavy elements.

With the new gun barrel-shaped atom-smasher, the scientists will fling the nuclei of atoms as heavy as argon, element 18, at target nuclei. In the past, the usual projectile has been the alpha particle, the nucleus of helium, element 2. With the bigger projectiles, it should be possible to get larger yields of the still-to-be-discovered elements, and make identification possible. The "Hilac" is now nearing completion.

Most of the isotopes of even element 102 will be too short-lived (as short as a second) to identify. But unusual isotopes with an odd number of neutrons will have half-lives as long as minutes, a requirement for chemical procedures needed in identification. These unusual isotopes are the hope of the modern "alchemists."

The identification of elements up through 105 may take five to 10 years, Dr. Seaborg said.

In the more distant future, he said, it should be possible to identify elements from 105 through 108 by means of their characteristic radioactivities.

Burners, Converters, Breeders Tried Out as Power Sources

Nuclear Power Reactors

by W. Kenneth Davis
Director, Division of Reactor Development, U. S. Atomic Energy Commission

➤ In considering the United States reactor development program, two factors should be kept in mind. The first is our long-range objective of economically competitive nuclear power in this country. This goal is difficult to achieve because we have adequate supplies of relatively cheap fuel as well as large, efficient, and economical conventional generating plants. In developing economic nuclear power we must, therefore, seek levels of efficiency beyond those which would suffice in most other areas of the world.

The second consideration is that we have no reason to believe that any single type of reactor system will satisfy the variety of our needs. As a consequence we are investigating many technical approaches to nuclear power. While this variety of approaches is partially attributable to the fact that we do not yet know which reactor concepts are the best, many other and equally important factors have influenced our program. For example, among these are: The need for nuclear power plants in a wide range of generating capacities; the need for a balance between burners, converters and breeders; the possibility that natural uranium reactors may prove more desirable than enriched reactors in some instances, and preferences as to reactor types which may be dictated by geographical locations.

Our power reactor program can be considered as going through three development phases which follow one another in logical sequence. The first is exploratory, dealing with basic research and development in such fields as metallurgy, physics, chemistry and heat transfer. The second phase is the reactor experiment. In this phase, a relatively small reactor is built and operated to prove the technical feasibility of a concept. Information is gained concerning such items as reactor and systems stability, control characteristics, actual corrosion rates and mechanical component behavior. The third phase is the prototype phase. In this stage of development, large scale reactors are built primarily for the purpose of demonstrating the economics of a certain system. While the prototype may not be economical itself, it *will* point the way toward improvements which will in turn, lead to truly economical power. In addition, the prototype will give experience in the operation of a nuclear power plant which must meet certain commitments as to delivery of power on demand.

Perhaps a fourth stage, that of full-scale commercial utilization, should be included but I think this might

more logically be considered as an ultimate objective rather than as a development phase.

All concepts proceed through these phases, unless they are eliminated along the line as unsuccessful or lacking promise. The selection of concepts promising enough to be carried through successive phases of development is one of the more difficult tasks faced by those administering a development program of this nature.

The Commission has assumed the responsibility of providing the basic technology for power reactor development. This work is complicated and costly, and the results are often uncertain. The design and construction of the prototype or demonstration reactors is another matter. Here the emphasis is on economics and reduction of costs. We know of no better way to achieve this end than to bring to bear normal business incentives. Hence, we have encouraged both the reactor designers and builders, and the utility companies to accept the primary responsibility in the construction of these prototype reactors. We have insisted on limited and well-defined amounts of assistance by the AEC. This is not because we wish to reduce our cost, but because we believe this leads to real progress on cost reductions. There is increasing evidence of a desire on the part of industry to move into the field of nuclear research and development. We have encouraged such participation in the development of new reactor concepts which industrial groups may have originated, and in as wide a variety of feasible approaches as possible.

We may theorize as much as we will about reactor possibilities but theory is of most value when put to the test of an experiment. It also seems clear that the need for different sizes of reactors in different locations can most likely be satisfied by more than one type of reactor. I will attempt to appraise the various possibilities at hand.

We now have several power reactor experiments under construction:

1. An experimental boiling water reactor. This unit will have an output of 5,000 electrical kilowatts and should be in operation early in 1957 at the Argonne National Laboratory.

2. An organic-moderated reactor experiment which will produce 16 megawatts of heat. This is also scheduled for completion in 1957, at the National Reactor Testing Station in Idaho.

3. An experimental fast breeder reactor with 17,500 electrical kilowatts capacity. This reactor is planned for operation beginning in 1959.

4. Three aqueous homogeneous circulating fuel reactors. One of these is being built at Oak Ridge National laboratory and is scheduled to be in operation by next February. The output will range from 5,000 to 10,000 thermal kilowatts.

The other two reactors of this type are smaller systems. One will have an output of 1,300 thermal kilowatts and the other 2,000 thermal kilowatts. They should be in operation at Los Alamos Scientific Laboratory by the end of this year.

5. A sodium-cooled, graphite-moderated reactor experiment of about 7,500 electrical kilowatts out-

put. This reactor is being constructed by Atomics International, Division of North American Aviation, under contract to the AEC, and should be operating late this year.

The reactor eperiments we have underway are but one phase of our program. We are also going ahead with studies of a number of more advanced concepts. One such study is for the design of a circulating liquid metal fuel reactor to have an output of 5 to 10 megawatts of heat. Another study is being made of the closed-cycle gas system with a view toward the design of an efficient, high temperature unit.

We are also initiating further studies of the feasibility of heavy water, natural uranium reactors as power sources. The choice between reactors utilizing enriched uranium and those requiring only natural uranium is a marginal one, and we believe the natural uranium type warrants further serious study.

I have not mentioned the pressurized water system in the same category as the other reactors since it has already demonstrated its applicability and, to some extent, the economical limits within which it can operate. Each of the reactor systems I have mentioned has certain advantages and disadvantages which must be carefully weighed when considering economic feasibility and the prospect of early utilization. We still do not have sufficient economic data on the basis of which any of these concepts can be eliminated. However, I will point out briefly the advantages and disadvantages of each type.

The pressurized water reactor has one large advantage just now — we know how to build and operate it and we can make reasonable estimates of initial investment. From a technical point of view, as well as that of public safety, it is one of the more stable and inherently safe systems of which we have knowledge. Although we are most familiar with this type of reactor, there remain two major disadvantages inherent in a pressurized water system, namely, high initial cost and low steam temperature. The first disadvantage can be overcome in a very large installation in which the high cost of the reactor may be spread over a large generating capacity. The PWR under construction at Shippingport, Pennsylvania, will provide further operating experience on this type of system. The generating capacity of this unit, the first large nuclear plant in the country, will initially be 60,000 electrical kilowatts, and it is expected that improvements in performance may raise this capacity to 90,000 electrical kilowatts. Financing is a joint AEC-industry affair.

The reactor having inherent safety characteristics most similar to those of pressurized water systems is the boiling water reactor. In this reactor we permit boiling to take place in the reactor core. The steam is then formed at essentially the temperature and pressure at which it will be used. It is easy to see that since the reactor vessel must operate at a pressure of only about 600 pounds instead of 2,000 pounds to deliver 600 pound steam to the turbines, the fabrication cost of the reactor vessel will be much less than in a pressurized water system. This saving in initial cost will not be confined to the reactor vessel alone but will extend to a large part

of the piping system. The resulting decrease in initial investment should lend this type to applications in medium capacity generating stations. However, one present disadvantage of the boiling water reactor is the possibility of radioactive contamination of the steam, in turn, leading to contamination of the turbine machinery. A possible safeguard against this condition involves the expense of an intermediate heat exchanger.

The initial costs due to expensive pressure vessels can also be avoided by utilizing some coolant other than water. One alternative is the use of sodium as a heat transfer medium. In a reactor of this type we can achieve high temperature at essentially atmospheric pressure. This high temperature may permit the generation of steam at temperature and pressure comparable to conditions found in the best fossil fuel generating stations. These advantages are offset to some extent by the necessity for more expensive containment materials, but it is still likely that the original cost of a power plant of this type will be no more than that of a boiling water system. The major economic advantage would then have to come from increased operating efficiency. A sodium-cooled system may prove to be quite flexible as to the power range over which operation will be economical. Both graphite moderated and fast reactors of this type are being developed.

As an alternative to the use of sodium as a coolant, an experimental reactor is under construction in which an organic material will be used as moderator and coolant. It is expected that this material will not only allow a substantial reduction in pressure vessel costs but, since the material is essentially non-corrosive, cheap construction materials may be used and the need for expensive fuel element cladding may be eliminated. The experiment now under construction will give data on radiation stability of the coolant and on the costs associated with the cleaning of the organic stream. These questions will have to be answered in order to evaluate the promise of reactors utilizing organics.

In all of the reactors I have been talking about a rather severe limitation on utilization of fuel is imposed by fuel element damage and poisoning due to fission product buildup. The necessity for regular shutdown to allow fuel element replacement is an additional obstacle to efficient operation. This obstacle may be overcome by using a fuel which is not subject to irradiation damage, which may be enriched while the reactor is in operation, and from which fission products may be removed without reactor shutdown. These requirements are met by a circulating fuel reactor and, as I mentioned previously, there are two distinct circulating fuel reactor types under development. In the aqueous homogeneous reactor the uranium may be in the form of uranyl nitrate, uranyl sulfate or uranyl phosphate in a circulating water solution. The water acts both as a moderating medium and as a heat transport material. This system must be highly pressurized. The corrosion problem in all of these aqueous reactors is severe but appears capable of solution. Fuel inventories are small in these systems. The cost, a very

high one, of reprocessing used fuel elements is eliminated, which contributes to the over-all operating economy of the reactor.

In the second circulating liquid metal fueled reactor, we may find the solution to two major problems — high core pressures and corrosion problems. The fuel proposed for this system, a uranium bismuth solution, will, we hope, permit the production of high temperature steam while maintaining the core at close to atmospheric pressure. It is believed that readily available construction materials may be used for the system and that fabrication will present no serious problem. The potential cost advantages of such a system are obvious and, while the chemical processes are different, the economic advantages occurring from fuel stability and continuous cleaning and re-enriching will be the same as in the aqueous homogeneous type. Reduction in initial construction costs should allow the economic operation of smaller plants as well as those of higher capacity. Furthermore, since the fuel has no adverse reaction with water, there is no danger from this point in using such a system in a ship or submarine.

The gas-cooled reactor, especially when operating in connection with a closed-cycle gas turbine, appears in some respects to offer possible cost advantages over other types. Some of the potential advantages are light weight, compact arrangement, ease of containment, low corrosion rates, and high efficiency. But there are many problems associated with the construction of such a system. Among them are the inherently difficult problem of control and stability, and the fabrication of satisfactory fuel elements. At the present stage of gas turbine development, this reactor type seems to be limited to the lower capacity sizes — up to perhaps 20,000 EKW. Our techniques are improving and we feel that in the reasonably near future we may be able to begin construction of a gas-cooled reactor experiment. We are interested in an efficient gas cycle and not in a unit where inefficient, low-temperature operating conditions lead to high operating costs.

Perhaps I have seemed to overemphasize the problems which remain to be solved, and the great strides which must be made if nuclear power is to become competitive. It goes without saying that problems cannot be solved before they are known. A few years ago, we could only imagine what problems might be faced. We now know that some of these imagined problems could have been ignored, but other much more real ones have taken their place. While we are sure that we have not found all the problems, we are confident that the solution of those we now recognize will move us well along toward our goal. These problems do not appear insuperable. They will not be solved easily, or overnight, or without considerable expense in time and money. The fact remains, nevertheless, that we have identified them and even this knowledge is in itself a major step forward.

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Present and Future Uses For Radioactive Products

Atomic Energy and Medicine

by CHARLES L. DUNHAM, M.D.
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➤ FOR THE FIRST forty years following the discovery of radioactivity by Becquerel the medical applications of this phenomenon were of two general kinds. There developed promptly a very widespread use of the penetrating properties of X-rays for diagnostic purposes. More gradually and to a considerably lesser extent the direct damaging effect of ionizing radiations on living tissues and organisms were taken advantage of in the treatment of malignant diseases. A limited number of applications was made in other fields of medicine, as in the indirect treatment of ringworm of the scalp in youngsters. In the experimental laboratory these radiations were used as experimental tools, especially in the field of genetics, beginning in the middle twenties.

There was one very striking exception to these generalizations. In 1923 Hevesy in Denmark used a naturally occuring radioactive isotope of lead to study by analogy certain facets of calcium metabolism in plants. He thus established the basic principles for the use of radioactive elements as tracers in the elucidation of biological processes.

In 1934 Joliot and Curie reported the first successful production of radioactive elements artificially. They bombarded with alpha particles natural boron containing boron 10 and natural aluminum, aluminum 27 which yielded nitrogen 13 and phosphorus 30 respectively, both short lived positron emitters. It remained then for Ernest Lawrence to invent the cyclotron, a much more powerful and flexible source of high energy particles than had hitherto been available. A considerable variety of radioactive isotopes could now be produced in quantities sufficient to explore their potential value in medicine as therapeutic agents and as tools in the study of metabolic processes. In 1936 John Lawrence first administered an artificially produced radioactive isotope to a sick human being with the express purpose of treating his disease. This event marked a milestone in the practice of medicine.

Since then the therapeutic uses of artificially produced radioisotopes, whether administered internally or used as a source of high energy gamma rays in teletherapy, have been in the limelight. The preoccupation of the medical profession and the public at large with the urgent need for more effective ways to treat cancer has largely been responsible for this. Nevertheless the diagnostic uses of radioisotopes already bid fair to out-

strip the therapeutic uses. The day to day use of radioactive tracers in fundamental research into the nature and causation of disease, though not publicized to the degree that the therapeutic uses now are, far exceed in variety and perhaps in eventual importance the diagnostic and therapeutic applications.

With the close of World War II and the ready availability of large quantities of neutrons at atomic reactors, the stage was set for full exploitation of radioisotopes in medicine, biology, agriculture and industry. Prior to the war only biomedical scientists who were fortunate enough to be associated with universities at which there were high energy accelerators in operation were privileged to have radioisotopes, and then only in limited quantity as cyclotron time could be made available for their production by the physicists.

On August 2nd, 1946, the first shipment of reactor-made radioisotopes was sent out from Oak Ridge. This signaled the present era of freely available artificially produced radioisotopes at reasonable cost to all comers who could demonstrate that they could use these new tools safely. By January 1st, 1955, there had been 64,202 shipments of radioisotopes amounting to a total of 54,728 curies of radioactivity. In the same period of time forty-six nations outside the United States had received 3,173 from this country alone.

What is being done with these isotopes? This is not the occasion to discuss the industrial and agricultural uses, exciting as some of these are, especially in the field of agriculture where the science of fertilizers is advancing by leaps and bounds in the wake of tracer studies with radioisotopes. Much as I am tempted to talk about these things I will confine my remarks to the field of medicine as promised.

First let us consider what is being done with radioisotopes in the treatment and diagnosis of disease. Radiation therapy has until recently been pretty much the sole province of the radiologists who have reluctantly tolerated encroachments by a few genito-urinary specialists, gynecologists and dermatologists. With radioisotopes freely available just about everybody is getting into the act.

The internists are using P 32 and other radioisotopes to treat a variety of blood dyscrasias, polycythemia rubra vera, certain of the leukemias and less effectively some of the lymphomas. They use radioiodine to diagnose various thyroid states and to treat hyperthyroidism and appropriate cases of thyroid cancer. They use I 131 to destroy the thyroid gland in order to control intractable angina pectoris, and selected cases of chronic congestive heart failure. Recently a similar approach seems to be proving helpful in cases of advanced emphysema. Radioiodinated human serum albumen is finding daily use in blood volume and cardiac output studies. Radioiron, Iron 59, is used to determine the status of the red blood cell formation function of the bone marrow while chromium 51 is used to tag red cells for measuring the red cell mass. A very simple test for absence of the "intrinsic factor" in pernicious anemia consists in administering cobalt 60 labelled vitamin B-12 by mouth and checking for

radioactivity in the urine. Radioactive iodinated Rose Bengal appears to be many times more sensitive as a test for liver function than bromsulphthalein.

For palliative treatment of generalized carcinoma of the abdominal or thoracic cavities radiogold and radioactive chromic phosphate are effective in reducing fluid accumulation in an appreciable proportion of cases.

The neurosurgeons are finding radioactive iodinated human serum albumen and radioarsenic important tools in the diagnosis and localization of brain tumors. They have also used radioisotopes to study the dynamics of the cerebrospinal fluid and the intricacies of the mechanisms involved in the blood brain barrier.

The ophthalmologists find radiostrontium applicators useful in treating benign growths of the sclera and P 32 has been found helpful in some clinics for localizing and in the diagnosis of intraorbital tumors.

Plastic surgeons use radiosodium to determine the adequacy of the blood supply in pedicle skin grafts. Genito-urinary surgeons use radiogold for interstitial treatment of prostatic cancer, and radiogold and other isotopes to treat bladder cancers. Some general surgeons today cannot bring themselves to close the incision on an inoperable abdominal cancer without either squirting some short-lived radioisotope into the tumor or sewing into the tumor hollow threads containing the isotope. Similarly there are those who treat cancer of the cervix with radiogold interstitially.

In experimental studies aimed at controlling disseminated metastatic cancer by destruction of the pituitary gland, implantation of radioactive materials in the gland have been used by some as a substitute for precise surgical removal. Meanwhile at Berkeley they are using the proton beam from the large cyclotron to accomplish the same result bloodlessly.

I have by no means exhausted the uses to which radioisotopes have been put in the practice of medicine, but I trust I have given you an idea of their variety. Whereas, to some, these applications seem to have been very slow in getting under way, I personally feel we may be approaching a time when we shall have to worry about fadism. There is already evidenced a tendency to do some things with radioisotopes just to show that it can be done that way whether or not isotopes constitute the best and simplest approach to the problem. In any event, it does not appear likely that any bets are going to be missed.

Before moving on to some of the other ways in which atomic energy activities are affecting medicine and its practice I would like to say a few words about possible future applications of tracer studies in intermediary metabolism and the promise they may hold for the future of medical practice. The diseases of "maturity" become increasingly important as the methods for control of the infectious diseases are more and more effective. Precise knowledge of the various disturbances of carbohydrate, lipid and protein metabolism, so little understood today will bulk larger in our efforts to control atherosclerosis, hypertension and perhaps even neuropsychiatric disorders. Many laboratories are today well along in such studies using radioactive isotopes in-

corporated into organic compounds. As the metabolic defects are pinpointed there is every reason to believe that diagnostic tests will be devised using these same techniques which will permit of early recognition and correction of the defect before irreparable damage has occurred. We have all seen what can be done with iodine 131 alone or in labelled compounds to detect aberrations of thyroid gland activity. Carbon 14 and tritium are the isotopes most likely to be the most useful ones in the future. Unfortunately, their beta radiations are of relatively low energy and consequently are not so readily detected as the gamma rays from iodine 131 or even the beta radiations from phosphorus 32. Furthermore for such studies and tests to be undertaken safely in relatively normal human beings the amount of these isotopes introduced into the body at any one study or test will have to be strictly limited. This means that the more conventional and standardized methods of counting will have to be superseded by much more sensitive methods such as those developed by Dr. Willard Libby for detecting traces of radiocarbon and radiostrontium. On the other hand I am quite confident that it will be only a matter of a few years before such tests can be carried out in a number of medical school laboratories and eventually in the doctor's office. The methods are known. It only remains for improved and relatively inexpensive and reliable instruments to be developed before we can rapidly move ahead in this work on a broad front. Meanwhile basic research with radioactive tracers in animal experiments has become a commonplace in the fields of nutrition, pharmacology, cancer research, carbohydrate lipid and protein metabolism, microbiology, immunology and fundamental biochemistry.

The things which I have been talking about up to now constitute some of the more readily identifiable contributions of the atomic age to medicine. There are going to be an increasing number of indirect contributions as well as time goes on. Let us see what the demand for more and more precise information about radiation effects on biological systems is bringing forth.

Take the problem of whole body radiation injury as was suffered by thousands of Japanese at Hiroshima and Nagasaki. One of the most important effects of a single large exposure of the whole body to atomic radiation is almost immediate, but temporary, suppression of bone marrow activity. There have already been uncovered a number of methods of reducing this effect if treatment is instituted prior to exposure. The amino acid cysteine given a few minutes before exposure reduces the effect by about half. Materials which injure the bone marrow, if given seven to ten days prior to exposure so that the exposure occurs at a time when the marrow is just beginning to recover, have a similar sparing effect. Irradiation at a time when the animal is temporarily deprived of adequate oxygen supply permits of increased chances for recovery. Furthermore embryo spleen brei, spleen homogenates and bone marrow injections administered within a few hours *after* exposure are also effective in promoting recovery. Apart from the

current lively discussions as to whether the latter procedures act by a cellular or a numberal mechanism all of this means to me that we are soon to know much more about the factors, enzymes, coenzymes and state of oxygenation of the tissues which control hemopoesis. Successful procedures for promoting prompt recovery of bone marrow damaged by radiation are bound to be useful in controlling some of the aplastic anemias encountered in day to day practice.

Premature aging is one of the residual effects of total body exposure to ionizing radiation. At present we are in the stage of defining the problem in terms of dose and dose rate. This is a non-specific effect in the sense that no single cause of death seems to be responsible for the shortened life span. As these studies move further into the problem, and as they begin to elucidate some of the mechanisms involved in the production of this effect their applicability to the hitherto baffling problem of the natural aging process will be apparent. Here for the first time we have an experimental tool — whole body irradiation — which can be used to study the aging process and incidentally to shorten greatly the time required for observation in life span experiments involving the longer lived experimental animals. Maybe before long we will be able to answer so simple a question as: "What precisely is aging?" or irrespective of chronological considerations "How old is Mr. Smith?" Perhaps we can even look forward to the day when the retirement age can be individualized and on a less arbitrary basis than is the case today.

Cancer is the most dramatic and for the individual probably the most important consequence of overexposure to ionizing radiation. This may occur in the form of leukemia as a result of overexposure of the whole body to radiation as has occurred in Japan, or it may be cancer of the bone as in the radium dial workers, or cancer of the skin as happened in the case of so many pioneer radiologists. It is for this reason that the Atomic Energy Commission has a very special interest in the cancer problem in addition to the fact that the great physicist, Enrico Fermi, died of cancer and Brian McMahon, the framer of the original Atomic Energy Act, also died of cancer. We spend annually some three millions of dollars of our research appropriation for cancer research, that is, for researches into the cause, diagnosis and treatment of cancer making use of the unique tools and byproducts of atomic energy activities — radioisotopes, high energy accelerators, betatrons, cyclotrons and even atomic reactors. We are at the present time building at the Brookhaven National Laboratory on Long Island a custom-designed medical research reactor, the first reactor ever to be devoted exclusively to medical research and principally to explore further the possibilities of using reactor-generated neutrons for the treatment of cancer. A promising beginning has already been made there by the medical department using the limited time (usually after hours) and improvised facilities available at the large Brookhaven reactor designed for research in nuclear physics and radiochemistry. Using the neutron capture reaction of boron 10 introduced into the tumor via the

bloodstream they have established the feasibility of this novel method of giving radiotherapy to deep-seated tumors. With the much higher neutron fluxes to be available from the new reactor they hope to produce positive therapeutic results in glioblastoma multiforms and other tumors in other parts of the body.

The Oak Ridge Institute for Nuclear Studies has played a major role in developing the use of cobalt 60 in teletherapy devices as a substitute for high voltage X-ray machines. Those who use these machines claim for them not only excellent therapeutic results, but less distressing radiation sickness. Recently this group has developed a device using a kilocurie radiocesium source. Cesium has two interesting advantages over radiocobalt, although the energy of its gamma rays is only about half that of cobalt 60 gamma rays and roughly equivalent to the output of a million-volt X-ray machine. Its half life is some thirty-three years compared with a little more than five years for the cobalt 60. This means that the cesium 137 sources will not have to be replaced so frequently as the cobalt sources. Furthermore, cesium is one of the longer lived fission product wastes from atomic reactors so there is potentially an almost limitless supply of the material provided economic methods of separating it out from the other fission products can be developed. The AEC is now building a pilot plant fission product separation facility where this problem will be tackled on a large scale.

The Argonne Cancer Research Hospital at the University of Chicago School of Medicine is exploring a variety of modalities for treating cancer. These include a 50 mev linear accelerator and a 1600 curie high specific activity cobalt 60 rotational teletherapy device. At the Argonne Cancer Hospital, at Brookhaven, at the AEC project at the University of Rochester and at other institutions we are sponsoring efforts designed to solve the problem of how to concentrate more effectively radioelements in tumor tissue — elective localization. Both the immunological approach and the metabolic approach are being thoroughly explored.

In addition to these direct attacks on cancer as cancer, a very large proportion of our work in radiobiology uses cancer induction as the end point, or uses experimental cancers and cultures of cancer cells as the biological system under study. All of these activities are grist to the cancer mill, and will make their unique contribution in varying degree to the eventual solution of the cancer problem.

Radiation cataracts result from overexposure to ionizing radiation, especially to neutrons. Our program of research in this area, involving as it does lens physiology and biochemistry, will contribute its bit to the science of ophthalmology.

The genetic effects of radiation are another of our concerns. We have a very broad research program in this field, both on-site at our major laboratories and projects and off site at universities, colleges of agriculture and agricultural experiment stations. Dr. William Russell's studies at Oak Ridge now involve more than two hundred thousand mice. We spent more than a million dollars on the

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genetics studies conducted under Dr. James Neel at the Atomic Bomb Casualty Commission in Japan. This was the first truly large-scale human genetics study ever undertaken, and is providing a base line for all future human genetic studies. It was not possible, as it turned out, to define precisely the genetic effect of the atomic bomb radiations on the populations of the two cities. Nevertheless what has been learned from this undertaking is already leading to improved methods for approaching that most difficult of all the areas of genetics research — human genetics. This heightened interest in genetics as a result of atomic energy activities is bound to result in new knowledge relevant to the so-called constitutional diseases and in all likelihood to cancer itself, whether the approach is of the more conventional sort or that pioneered by Dr. Theodore Puck of the University of Colorado School of Medicine, who has demonstrated that it is possible to study human cellular genetics by using tissue culture techniques. By now if I have not exhausted the list of direct and indirect benefits of atomic energy activities to medicine and medical practice, and I have not by any means, I may already have exhausted you. Nevertheless there is another side to the coin. I would be remiss if I did not discuss it.

Any cell which has been irradiated has suffered an insult of a greater or lesser degree depending only on the amount of radiation received. The induction of a favorable mutation is a very rare exception indeed. It is, of course, this injurious effect of radiation which makes it essential that all unnecessary exposure to ionizing radiation be avoided. To put it another way there should be no exposure of persons to radiation without at the same time some useful purpose being served for the individual or for the group. In fact, we should go one step further as has been recently urged in the report of the National Academy of Sciences-National Research Council on the biological effects of atomic radiation. Even when a useful purpose is served, whether in industry, in national defense, or in the practice of medicine, all radiation exposures should be kept at a minimum, especially exposures to the germ cells.

A few years ago only a relatively few persons, radiologists and a small number of physicists were in a position to be injured by radiation. But now the evergrowing atomic energy industry has swelled this number to many thousands. Although remarkably few radiation injuries have been recorded to date in spite of the rapid expansion of this work and the fantastic quantities of radioactivity handled today, it is absolutely essential that every physician and medical student become conversant with the biological effects of ionizing radiation and the diagnosis and treatment of the various types of radiation injury in both their acute and chronic or late manifestations. This is important not only so that the physician can recognize and give appropriate treatment for radiation injury when it occurs, but also in order that he can reassure his patient that his symptoms are not due to radiation if indeed no overexposure has occurred. There is quite a natural tendency

today for a person to attribute any illness which he may have to his prior or to his present occupation. Similarly, if he lives in the neighborhood of an atomic energy plant or of a weapons testing activity he may attribute that illness to radiation exposure resulting from these activities. His physician must be prepared to give him guidance in these matters and to determine for him whether or not his illness is at all likely to be a manifestation of radiation injury. We have had everything from German Measles to a simple Exfoliative Dermatitis brought to our attention as supposed manifestations of radiation injury.

A whole new field of industrial medicine and industrial hygiene has opened up with the growth of the atomic energy industry. To help meet the need for trained personnel in this field the AEC has established a number of traineeship type special fellowships. Some sixty-to-seventy fellowships in health physics are granted each year which provide for nine months of academic training at Vanderbilt University, the University of Rochester and the University of Washington, followed by three months on-the-job training at Oak Ridge National Laboratory, Brookhaven National Laboratory and the Hanford Works respectively. Six or seven fellowships are granted each year for special training in industrial hygiene at Harvard and at the University of Pittsburgh. In industrial medicine proper we grant seven or eight fellowships each year for special training at the Harvard School of Public Health, the University of Rochester School of Medicine and Dentistry, the University of Pittsburgh School of Public Health and at the University of Cincinnati School of Medicine. These medical fellows are then offered a year of on-the-job training at one of our major sites, or they may take another year of academic work before their on-the-job training. Frankly, the demand for personnel with this sort of special training is so great that we could double this program if there were sufficient numbers of qualified applicants.

Finally in the event of an atomic war the physician must be prepared to evaluate and treat radiation casualties whether he is in military or civilian practice. Radiation injuries as they are likely to be encountered on a large scale in an atomic war should not be approached as something bizarre and strange. They present no symptoms not well known in the normal daily practice of every physician. They consist in nausea, vomiting, diarrhea, purpura, oral and gastrointestinal ulcerations, gross hemorrhages and the like. The blood picture of pancytopenia is no novelty either. The sequence of events and the appropriate use of presently available therapeutic agents can easily be mastered if the physician will only take a little time to it. The nature and induction time for late effects of overexposure are quite well known. The present areas of uncertainty in our knowledge relate principally to the precise dose and dose rate relationships to the specific effect rather than to the nature of the effects themselves. And even as to doses we can today bracket them in terms of effects produced with sufficient accuracy so that

the National Committee on Radiation Protection can recommend maximum permissible occupational exposure levels with considerable confidence.

In short, the by-products and tools of atomic energy bid fair to making contributions to medical science and the practice of medicine as great as have been made in the past by the microscope itself. At the same time they have added new responsibilities to those of you who work in the medical sciences, and those who practice the art.

Salt and Soda for Burn Shock

➤ DRINKING large amounts of salt and soda solution is effective emergency treatment of shock due to burns, Dr. Kehl Markley, U.S. Public Health Service, reported in the Journal of the American Medical Association.

Dr. Markley's report is based on three and a half years of study of the treatment in three cooperating hospitals in Lima, Peru. Associated with Dr. Markley were the following Peruvian physicians: Drs. Manuel Bocanegra, Augusto Bazan, Roberto Temple, Miguel Chiappori, Guillermo Morales and Alberto Carrion.

Among 110 children and 83 adults, all severely burned, no significant difference in deaths was found between those given salt and soda solution to drink and those given conventional anti-shock treatment of blood, plasma or plasma extenders injected into the veins.

The salt and soda treatment was shown effective in laboratory animals in earlier studies by Dr. Sanford Rosenthal and associates of the Public Health Service.

The Lima study was done to evaluate the treatment in humans because of its possible usefulness in case of mass catastrophes.

On the Back Cover

➤ INSIDE THE CORE *of a pressurized-water type nuclear reactor is simulated by the exhibit pictured on the back cover. This reactor core will power the Army Package Power Reactor (APPR) being built by Alco Products, Inc. at Ft. Belvoir, Va. for the Army and the Atomic Energy Commission. The project is expected to be in operation early in 1957.*

A hypersonic missile flying at 90,000 feet altitude at eight times the speed of sound (5,390 miles per hour) is subjected to an approximate temperature of 1,500 degrees Fahrenheit.

New Chemical Patents

To obtain copies of these new patents, order them by number from the Commissioner of Patents, Washington 25, D. C. Enclose 25 cents in coin, money order or Patent Office Coupons (but not stamps) for each patent ordered.

Salt Bath Gives Purer Metals

➤ A SERIES of salt baths promises to provide producers with a much purer form of metals such as titanium and zirconium than has heretofore been possible.

Use of the patent for this process will result in the production of metals normally contaminated by oxygen, nitrogen and carbon, in either ingot or coalesced form, free of carbides, oxides and nitrides.

In operation, a metal powder suspended in sodium chloride is first filtered mechanically using the molten slurry of salt and the suspended powder. The partially purified metal is then washed with an excess of a wash salt such as aluminum trichloride which is liquid at relatively low temperatures.

The bulk of the aluminum trichloride is separated from the metal powder by filtration and then evaporated. After consolidation, a purified form of the metal is obtained, prior to its exposure to air.

The improved process for metal production is the invention of Gordon R. Findlay of Bedford, William O. Di Pietro of Watertown and Ralph S. Hood of Marblehead, Mass. They received patent No. 2,760,858 and assigned the patent rights to the Monsanto Chemical Company of St. Louis, Mo., and the National Research Corporation of Cambridge, Mass.

Oil Waste Soil Aid

➤ SOIL STRUCTURE can be improved by putting into heavy clay soil up to 25% by volume the spent clay used in refining lubricating oils and petroleum distillates.

The invention of Robert Earl Emond of Mooretown, Ontario, Canada, the use of the petroleum refinery spent clay with clay soils changes the structure so that the soil becomes more workable, porous, easily drained and warmer.

Calling his find a "new unexpected effect," Mr. Emond cites field tests with gladioli, potatoes and onions which bear out his claims. He says that indications show the spent oil additive clay to be effective for at least three years.

The soil structure aid earned Mr. Emond patent No. 2,760,308. He assigned the patent rights to the Esso Research and Engineering Company of Delaware.

Solar Energy Devices

➤ TWO INVENTORS, thousands of miles apart, received patents for appliances that use the energy of the sun for power. Robert B. Olsen of Idaho Falls, Idaho, invented a solar energy cooking apparatus designed for use

as a furnace for converting coal and steam to coke and by-product gases. Across the Atlantic, Adnan Tarcici of Taiz Par Sana, Lebanon, invented a solar energy device for household cooking.

Mr. Olsen's invention uses a parabolic reflector base covered by many small flat mirrors. Capturing the rays of the sun and directing them to operate the sun furnace, Mr. Olsen claims that this can be done very cheaply. He was awarded patent No. 2,760,920.

Mr. Tarcici's invention uses a parabolic mirror of one piece. The solar cooker turns with the concentration of the sun. He was granted patent No. 2,760,482.

Enzymes Keep Flavor

➤ A METHOD of producing condiments from mustard seed, garlic, onions, radishes and chives wherein the flavor is preserved by keeping the enzyme action intact is the invention of Nicholas S. Yanick of Chicago, Ill. Granted patent No. 2,760,869, Mr. Yanick assigned the patent rights to the Kraft Foods Company of Chicago.

Smooth Steel Ingots

➤ STEEL ingots can now be cast free from surface imperfections and defects. The invention that makes this possible eliminates poor surfaces in rolled or forged steel products.

Heretofore, steel makers have had no satisfactory means of preventing blemishes on steel ingots caused by the surging of the metal during top casting.

Now, however, Nicholas J. Grant of Winchester, Mass., has invented a consumable glass fiber ingot mold liner, which he claims:

1. Prevents the splash from contacting the walls of the mold while, at the same time, it minimizes the splash and then melts away.

2. Leaves no large amount of residue.

3. Has a low vapor pressure and is inorganic.

4. Is non-reactive at high temperatures and does not form other products with the metal.

5. Is a poor conductor of heat.

6. Is relatively inexpensive and easy to install.

Mr. Grant received patent No. 2,763,043 and assigned the patent rights to Lukens Steel Company of Coatesville, Pa.

High Electron Curing

➤ A MEANS for vulcanizing silicone rubber by irradiation has been invented. Its use eliminates the need for chemical curing agents and heat in converting organopolysiloxanes to a solid elastic product.

Conversion with high energy electrons is independent of the dose accumulation rate of electron irradiation, but is dependent on the total dose, the vulcanizer's inventors, Frederick M. Lewis of Ballston Lake and Elliott J. Lawton of Schenectady, N. Y., state.

Products resulting from irradiated curing are useful for making tubing, electrical insulation, shock absorbers, and gaskets for high temperature use. "Because of their improved heat resistance," the inventors point out, "they are valuable as materials for use in applications where natural or other synthetic rubbers may fail owing to the deleterious effect of heat." The irradiated silicone rubbers keep

their flexibility at low temperatures too, being pliable in weather at least 60 degrees below zero Fahrenheit.

The vulcanization invention was granted patent No. 2,763,609. The inventors assigned the patent rights to the General Electric Company of New York.

Ferroalloying Material

➤ HENRY BRUCE MEGILL of Spokane, Wash., has invented a vacuum furnace process for making a low carbon ferroalloying material containing at least two alloying metals. One of the metals is derived from the group of ferroalloys such as ferrochromium and ferrotungsten. The other is from a material containing an oxide of nickel or cobalt.

The product of such a process, Mr. Megill says, can be readily applied in the production of alloy steels. For what results, he points out, is a three-metal furnace additive for use in making stainless steels.

He was granted patent No. 2,763,-918 and assigned the patent rights to the Chromium Mining & Smelting Corporation, Ltd., Sault Ste. Marie, Ontario, Canada.

Plant Growth Promoter

➤ BIGGER plants can be grown when fed a mixture of coconut milk and known plant growth regulants, such as 2, 4-D. The coconut milk comes from mature nuts. The mixture proved effective in promoting the growth of potatoes in tests. The plant stimulator is the invention of Drs. Frederick C. Steward of Cornell University, Ithaca, and Samuel M. Caplin of the University of Rochester, N. Y. They earned patent No. 2,-763,540.

Blue Rutile Crystal

➤ A SINGLE crystal of blue rutile, one of the three known crystal modifications of titanium dioxide, has been invented by Leon Merker of New York City. Mr. Merker claims that the crystal, which can also be obtained in a color range varying from bluish-white to blue-black, has gem-like properties and a reflectance, refraction and brilliance "greater than that of a diamond." He won patent No. 2,763,558 and assigned the patent rights to the National Lead Company of New York.

Depth of Layers of Fat

➤ LIVESTOCK men can now determine the thickness of fat and/or muscle on the body of a live animal.

The device that makes this possible is the invention of Drs. Randall M. Whaley of the department of physics and Frederick N. Andrews of the department of animal husbandry at Purdue University, Lafayette, Ind.

The Indiana scientist team explain that the packer is not able to assay the animal on the hoof accurately, and pay the hog raiser according to the true market value in terms of quality which consists in this regard in a desirable ratio of dressed out muscle to fat.

To overcome this need, the inventors have perfected a method whereby the difference in the specific electrical conductivity of muscle as compared to fat can be used to determine the depth of layers of each on a live animal. This is done with electrodes and a measuring device. The scientists were awarded patent No. 2,763,-935 and assigned the patent rights to the Purdue Research Foundation, Lafayette, Ind.

Book Condensations

ATOMS AND PEOPLE — Ralph E. Lapp — *Harper,* 304 p., $4.00. After starting on his career in science, the author decided to take a look at the extent to which the atom would remake the world. Now, he says, it is eight years since he has seen a paper marked "secret", but he feels this is not a handicap but an advantage.

THE CULTURE AND MARKETING OF TEA — C. R. Harler — *Oxford University Press,* 2d ed., 263 p., $4.00. Telling of the chemical composition of tea and of how it is grown in Asia, India and Indonesia. Also discussing the possibility of growing it in Africa, Australia and the U. S. S. R. where machines for picking the leaves are being tried out.

CHEMICAL AND MECHANICAL STABILIZATION — L. D. Hicks and others — *Highway Research Board,* Bulletin 129, 110 p., illus., paper, $2.25. Discussing the treatment of various kinds of soil for roads from Iowa loess to the "ball-bearing" sands of Arctic beaches.

HANDBOOK OF CHEMISTRY: A Reference Volume for All Requiring Ready Access to Chemical and Physical Data Used in Laboratory Work and Manufacturing — Compiled and Edited by Norbert Adolph Lange assisted by Gordon M. Forker — *Handbook Publishers,* 9th ed., 1969 p., $8.50. Containing for the first time physical properties of the earth and atmosphere, cosmic abundance of elements, occurrence of elements in the human body and other data of wide usefulness.

BIOLOGICAL TREATMENT OF SEWAGE AND INDUSTRIAL WASTES: Volume I, Aerobic Oxidation — Brother Joseph McCabe and W. W. Eckenfelder, Jr., Eds. — *Reinhold,* 393 p., illus., $10.00. Covering proceedings of a conference on biological waste treatment held in New York in 1955.

CURRENTS IN BIOCHEMICAL RESEARCH 1956 — David E. Green, Ed. — *Interscience,* 697 p., illus., $10.00. Summarizing the work of a decade on the great scientific puzzle of the chemistry of life.

A RAPID MATCHING TECHNIQUE FOR SEMI-QUANTITATIVE SPECTROCHEMICAL ANALYSIS — Edwin S. Hodge and William K. Baer — *Mellon Institute,* 5 p., illus., paper, free upon request direct to publisher, 4400 Fifth Ave., Pittsburgh 13, Pa.

THE CHEMISTRY OF PETROCHEMICALS — Melvin J. Astle — *Reinhold,* 267 p., $6.50. The beginning of the petrochemical industry was in the early 1920's when ethylene glycol was made from ethylene by way of the chlorohydrin process. By 1955 more than a fourth of all chemicals produced in the U. S. are petrochemicals.

PHYSICS FOR EVERYBODY — Germaine and Arthur Beiser with foreword by Henry A. Barton — *Dutton,* 191 p., illus., $3.50. A lot of fun, Dr. Barton says, and a lot of stimulation and some real mental sharpening can be found in physics without knowing any mathematics beyond arithmetic and the very simplest concepts of algebra.

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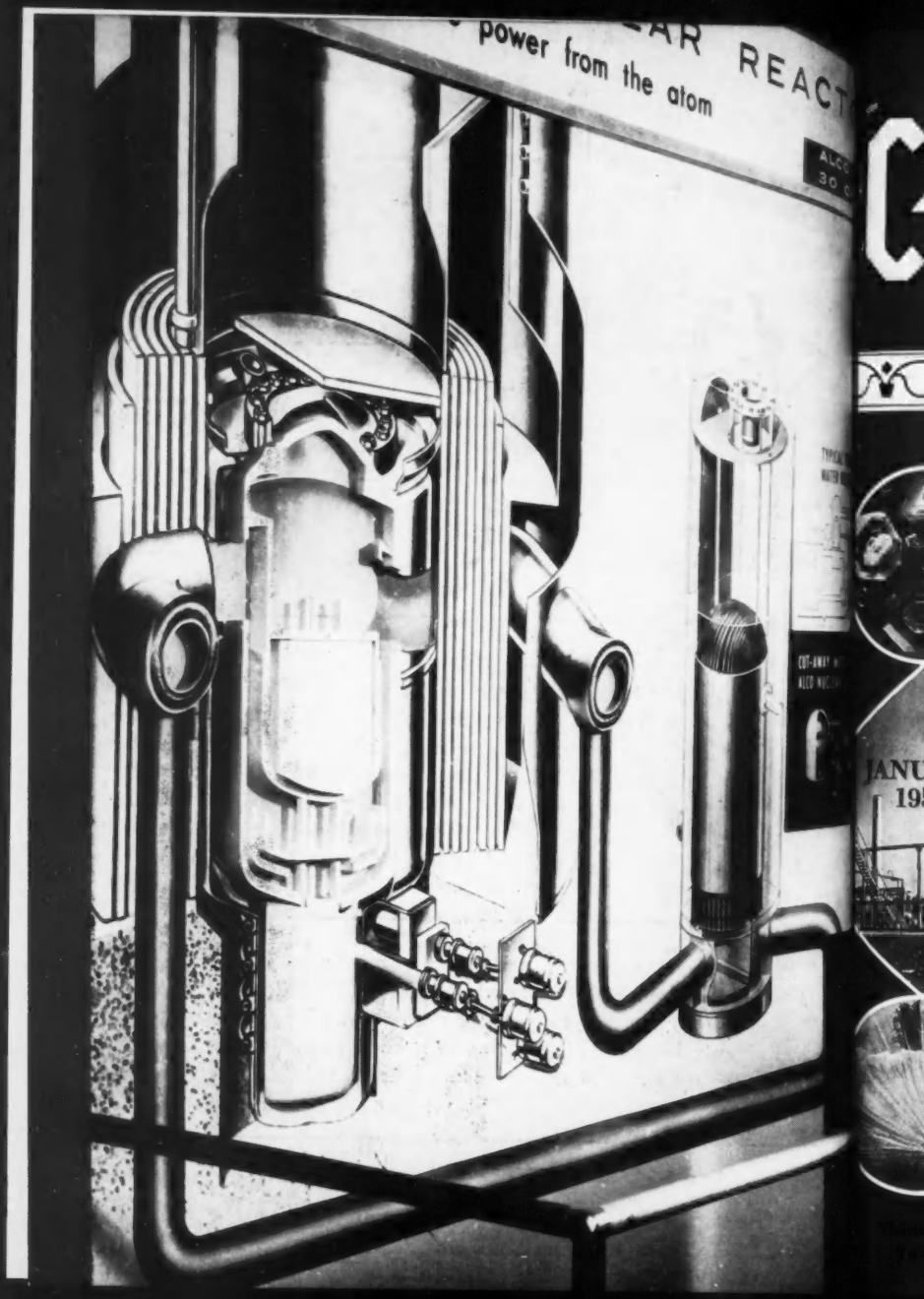

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